E.Stone, an archive for the Sardinia monumental witnesses

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Abstract. The "E.Stone" project is based on the survey, documentation inve gation and physical, geochemical and petrographic characterisation of the gr zoomorphic and phytomorphic stones of Sardinia. The name chosen to indic this project means the full value of these stones, standing before the beginn of human history. The main task of this project is to survey and to docum with an accurate laserscan survey, supported by topographical survey integrated by GPS tracing and photographic and photogrammetric survey supported by specific investigations on the rock characteristics. The further velopment of the collected data will be aimed to the definition of a digital "st of the knowledge" about the stone. This research will produce two main be fits: the creation of a clear and stable archive of these monuments and on second hand will create the possibility to reply at any distance, a copy in material of the original item.

Keywords: Stones, Sardinia, Landscape, Laserscan, Survey, Geology, Dec Modelling, Documentation.

1 The E.Stone Archive

1.1 Background

In the world of humanity there are two kinds of processes which are always p natural processes and the anthropic processes. These manifestations taken times and conditions to evolve; some of these mutations are clearly visible in lifetime, others take few instants, while certain requires millenniums or even r years to complete their cycle. In this way if we think to a stone on a seaside, s the sea and by the wind, it comes immediately clear how long it will remain a and in its conditions if compared to a bare foot impression left by a man on th simple human sign will have a duration of some seconds or maybe of some m first wave will erase the trace. But even with this meaningful difference, in ou are able to damage or even completely demolish the whole patrimony of m rocks which is richly present in the Sardinia Island. Sardinia is the larger Isl Mediterranean Sea and is the place some meaningful natural masterpieces

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very ancient rocks, with some formation coming from an age far more then 50
of years from our time, create a great emphasis about these stones, giving
server a great impression which goes far behind the simple surprise happeni
of some natural wonder.

The name chosen for this project is “E.Stone, an Archive for the Sardi
mental Witnesses”, the reason for this choice are first of all linked to th
approach to the research, which is based on advanced digital tools, so t
“Electronic” is placed in front of the word “Stone” written in English also i
ian version of the name to underline the intention to share and to dissemi
contents at an international level. The term “Witnesses” is used according to
often used in geology to refer to the rocks testifying a previous condition. T
the term "monuments" should be understood in its value described in the de
the Treccani vocabulary: "[...] to indicate what, for its size, is giving an imp
grandeur and solemnity [...]".

Fig. 1. The stone and the footstep, two different times

1.2 Documentation and Dissemination

To allow the preservation of these monuments the first step is knowledge, bu
as a theoretical work ending in itself but as a passage of awareness based on
nation process. The tools available today make it easier and more versatile tha
fore. In this way, this particular monument will be treated like they deserve

The digital survey tools and the advanced investigation solutions comb high-tech multimedia presentation may found in three-dimensional mod right place to be focused, with the opportunity to realize different levels of The creation of a repository of knowledge based on accessible criteria a dimensional access, will in time allow to repair or even to rebuild, if neces when the monument should be seriously damaged.

Procedures based on a wide digital approach, from a massive use of lase vey to the digital modelling aimed to produce multimedia contents, can s ously be a process of effective disclosure of this environment, allowing user over the world to view, study, explore these monuments and learn more abo ritory that they have all around.

The possibility to use both the current prototyping techniques to produce total reproduction of these items in different material can operate in three m the creation of "spare parts" for the monument, the reconstruction of the monu the easy and effective deployment in museums, exhibition areas or schools visitor will be able to touch the shapes of the monument. (and this will be a g sion for the blind or visually impaired as well as for the people with norma this way, developing well oriented models, it will be possible to disassemble stand, to build innovative learning paths based on digital/physical models.

1.3 Decay Analysis for the Monumental Witness

Through the study of the geomaterials which are the natural constituents of ments of high historical and cultural significance examined here, it will be p evaluate the state of alteration and the causes that may have led the chemical cal alteration. The intent will be to further investigate these issues, trying, on t the results, to propose strategies for the conservation operating before then an phic issue can take place. Operationally, all the monuments will be studie about their minero-petrographic and physical characteristics, including variou macroscopic alterations and their distribution in the same monuments.

1.4 The E.Stone Project

If adequate resources will be found, the project will develop a first progra year, at the starting phase of the project it will be immediately activated a space to allow collaboration between the research teams. Within the first s of activity the main campaigns of survey and documentation will start, in sampling and study of geomaterials from the monuments, the archive will b formed immediately and simultaneously, together with the progress of the and study of the collected data.

A first task in the survey campaign will be the completion of the docu about some of the main witnesses of Sardinia, including: Elephant Stone ne sardo (surveyed in 2006), the Bear stone in Palau, the remains of the turtle of the other stones with zoomorphic or phytomorphic shapes around San Te

(Cuglieri), the monolith (also know as “the shaped cake”) on the Pulchiana M in the Gallura area, the San Giorgio’s staircase in Osini. For each of the monuments it will be also catalogued and stored all the data on the com characteristics, state of alteration and possible methods of restorative inter case of the presence of strong chemical and physical deterioration.

As told before, the survey will be operated with the use of laserscan uni of phase-shift or time of flight technology, will be choose according to th survey condition, certain monuments will require long range scanner to be c documented, other will require an high level of detail from the close range tage of the phase shift solution, which is capable to measure a range equa dome (320 vertical degree and 360 horizontal degree) with an accuracy u millimetres collecting up to 200.000 points for each operative second, make of laserscan very interesting a reduce the operative time, but when the opera will need to operate from a meaningful distance, a slower, but more reliab flight solution will be used. The entire survey, conducted using even diffe will allow the full coverage of the investigated object. The survey will be l specific topographic network, and then referenced on the national map, this a solid archiving of the collected data and fully useful for all subsequent processing and analysis. The main steps of processing the data will be made development of traditional two-dimensional representations, views zenith, p vations, sections, useful to present the object using representation solutions w be easily understandable and communicable. After this phase, the survey da used to develop a three-dimensional digital surfaces model, with a procedure preserve the greatest correspondence between the collected points and the fi These models will be useful for the analysis and the study about the surface shape of the object, they will be used to study specific functions and, whe with photographs, to create images of graphics rendering.

Starting from these models, a complex process of treatment of the data duce a new series of three-dimensional digital models, designed for onlin and implementation of multimedia products.

The stage of treatment completion will include the implementation of dig els for the 3D printing of physical models, produced with additive or s processes with 3D printers which are becoming more common with. In this models allow users to access downloadable versions of the scaled digital mo specific machines, to print and create scaled versions of these monuments.

The models will allow reproducing a copy in resin, PVC or other econom rials, depending on the technology available. The production process of a model can be very simple, and in most cases it is very economical. In this w be possible to envisage the possibility of reconstructing an entire remote co the monumental witness. Any school or association in the United States, Sou ica, Australia or Japan, will be able to receive digital data a start to build sca or even real-sized models. This solution will allow also the access to th monument to blind and visually impaired people, they will be able to exper understand the shapes of these stones thanks to tactile models.

with a common printer on paper to be transferred to appropriate thickness cut manually. So, starting from the digital model and following simple insta structions, everybody will be able to get a scale models absolutely affordab cessible to all.

E.Stone project, step 1: Setting up an Internet space for data sharing. At ning an Internet space will be activated on the network for sharing and col between the research groups. In this way the data previously collected, bib references, iconographic, photographic, geographic references manuals and mation useful for the development of the project, will be kept continually u this collaborative space, based on classical protocols for remote sharing a conferencing will be possible to solve the main participation trouble a groups. At this stage, only active members of research teams, will access to plete materials under development. However a small part of the whole resear as a "preview" of the site will be activated to facilitate the dissemination o tion about the ongoing activities.

E.Stone project, step 2: Defining a catalogue about the state of knowlec elements of the research. This important step will have a rapid developm first phase of the project so it will be used to plan the survey and documenta paign. This phase will be based on the development of an online database.

The creation of this catalogue will determine the complexity, scientifi conservation status, risk status and accessibility or each monumental witness

E.Stone project, step 3: Starting the survey and documentation campaig sampling and analysis of geomaterials. During this phase an intensive ca survey will start. The operations program will bring the survey units to c various monumental witnesses. Regarding the study of geomaterials in the r tal witnesses, it is expected to develop individual campaigns, with durat some days for each of the monumental witnesses; in this time the study macroscopic characteristics of lithological materials will be done, the mat ples will be collected and the forms of alteration detection will be perform one of the monuments of major importance will be the subject of the surv cific workshop / seminar will be organized, it will be opened to the local tec erators who handle land management (municipalities, provinces, Soprin scholars, students of schools and the professionals who work in Cultural He Landscape, as architects, engineers, geologists, archaeologists, surveyors, etc

The operations of this phase will collect a huge volume of data and wid nation of the ongoing works.

E.Stone project, step 4: First morfographic data processing, informatio Once the phase of collecting information will be completed and treated to early accessible and "cleaned up" set of models, three-dimensional models printouts, photographic and textual data will be made homogeneous acc common standards for the research groups, structured in accessible forma phase, data collection will enrich the catalogue database of monumental with a substantial increase in the state of knowledge about these elements.

broadcasting and public access through the project site. The production str
the models will be organized around three main lines of development m
online viewing with photorealistic features; models for specific informatio
(decay, thematic maps, etc ...); for 3D printing process solutions.

E.Stone project, step 6: Interpretation of data about geomaterials pro
change and proposals for the preservation of monumental witnesses. The
and analysis on the collected data going to store them into the database
E.Stone. In detail, all geomaterials which are in the selected monuments wi
ied in detail, the geochemical characteristics (fluorescence, spectrometr
mineral-petrographic (optical microscopy and X-ray diffraction) and physic
teristics. The analysis of materials will be mainly done on the outcropping
parts which formed the area around and not directly on the witness. This
define the causes and processes of ongoing deterioration in the each mor
proposal about intervention strategies for restoration and preservation will
on the results of this phase.

E.Stone project, step 7: Dissemination of Information. A version for easy
catalogue of monumental testimony will be posted on the site of E. Stone. T
dedicated to access to three dimensional models and the section about multi
terials will be inaugurated. The models will be set available for users of E.S
the ability to request access to the specimens and recording. The informatio
progress of research will be disseminated through the traditional forms o
and discovery of information from the Internet.

E.Stone project, step 8: Consolidation and management of the Internet
space. At the end of the phase 7, the site of E.Stone will continue its grow
plementing a structure to make possible to access the Web geography
(Google Earth and similar systems). The areas dedicated to individual m
witnesses will enrich the discussion forum with the participation of users o
project that this will contribute by adding their own images, reports, in
about the "large stones of Sardinia" in this way users will be more involved
and will also give the opportunity to ensure a continuous update about the
of the monuments, forming a sort of "public" monitoring.

E.Stone project, step 9: When the E.Stone website will arrive to complete
tasks and to present exhaustive set of information about the monuments a
seminars and workshops in the area. Will take place, the techniques, proce
technologies used for the E.Stone research will be shared with activities o
dinia Island and with Internet based learning, the online seminars will be str
such a way as to ensure maximum usability by different users (students, sch
fessionals, technicians). The double activity about learning, with direct
and online seminars will be done to allow the better dissemination of the res

1.5 Expected Results

- Creation of an online documentation centre about the "monumental wi
Sardinia" that will determine the methods and a reference for the ma
and processing of this data.

- Sharing and dissemination of knowledge; networking with other groups
ars, to promote and enhance the state of knowledge and the state of
dealing with this category of heritage subject.
- Creating the conditions to allow a better approach to conservation and r
of this particular stones.

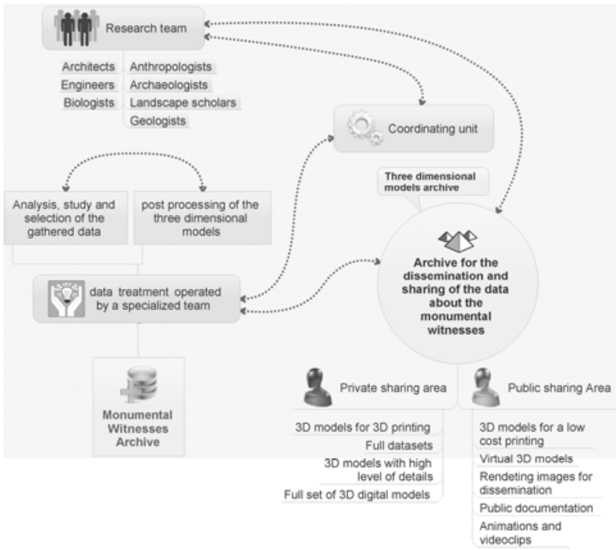

Fig. 2. Schematic view of the E.Stone archive project

2 What Was Done Until Today

At the time for this project/work two stone monuments were examined: the
of Castelsardo (Anglona, north Sardinia) and the Mushroom of Carloforte
San Pietro Island, southwest Sardinia). For the first stone operations in the
activities were set up: 1) laserscan technology complete survey 2) study
forms of macroscopic alterations and their distribution in the same stone; 3
of small sample from the stone monument; 4) experimental determination of
geochemical and petrographic characteristics of geomaterials by laboratory
using many instruments: helium pycnometer, polarized microscope, electron
scope (SEM), X-ray diffractometer (XRD), X-ray fluorescence spectromet
etc.; 5) interpretation of first data of laserscan survey and laboratory an
evaluate the grade decay and the causes of chemical and physical alteration
terials. For the second stone, the work activities were limited only to the
points: 1), 2), 3) and 5). The end of this study, based of the results obtaine
proposed strategies for the conservation of stone monuments.

of the Sardinian Cenozoic volcanism that forms a magmatic arc running
western margin of Sardinia and southern Corse microplates (Lecca et al.
references therein).Volcanic activity, with a calcalkaline affinity l.s., began
Miocene (around 32.4 My ago; Beccaluva et al. 1985, Savelli 2002 and
therein) producing basaltic and andesitic lavas and ended about 13 11 My a
ing a climax between 23 and 17 My. From 23-22 My onwards (Beccaluva e
and references therein), highly explosive ignimbritic fissural emissions wi
rhyolitic composition occurred simultaneously and with alternating basaltic
sitic lavas in various parts of the island, mainly along the western gra
volcanism, whose products crop out in vast areas of Sardinia, is generally re
a subduction of oceanic lithosphere in a N-NW direction along the Europ
nental paleomargin that produced the Oligocene rift between Sardinia and
(Cherchi & Montadert, 1982). The volcanic activity preceded and partly acc
the opening of the western Mediterrean sea through the formation of the
Balearic and Algerian basins. This lead to a 60° counterclockwise rotation o
Sardinia blocks around a pole located at 42.7° N and 9.6° E (Gueguen 1995)

2.1.1 Anglona Area

The crop out of Elephant ignimbrite is located in the northern of the Oligo
Sardinian Rift, in Anglona (north Sardinia). In this area three extensional p
be recognized in this area during a fifteen million year period which spanned
Sardinia continental microplate separation and Western Mediterranean back
opening (Sowerbutts, 2000). The first phase, initial late Oligocene extension
half-graben geometry with syn-rift clastic deposits shed locally from faul
highs, passing laterally to lacustrine marlstones. Calc-alkaline volcanic act
sequently predominated as volcanic centres developed along one half-grabe
ing fault, producing voluminous pyroclastic and epiclastic material. Seco
mid-Aquitanian–early Burdigalian extensional faulting, recognized from
clastic syn-rift stratal wedges, truncated and subdivided the half-graben. Th
sediments were sealed by a regionally correlated ignimbrite that in turn was
late second-phase faulting. Third phase extensional fault movement, whi
vated the original fault trend then occurred. The pyroclastic rocks of Anglo
strong heterogeneity, as the result of different eruption conditions and em
temperatures (high- to medium- to low-grade ignimbrites). Scatter also de
the different incidence of pumice, crystal and lithic fragments and matrix.
their volcanological the pyroclastic rocks were divided into two mai
1) pyroclastic flow deposits with high- to medium-welded grade (including
ignimbrites), from poorly to medium porous; 2) pyroclastic fall deposits
welded grade (e.g. cineritic products), from medium to strongly porous.

2.1.2 Volcanic Island of San Pietro

The crop out of Mushroom pyroclastic rocks is located on the San Pie
(southwestern of Sardinia), completely formed by volcanic rocks belongi
Cenozoic Sulcis complex (Garbarino et al. 1985; Garbarino et al. 1990). I

gionally extended calc-alkaline activity. In a first, has a calc-alkaline volcan than 15 My) with a character fissural and led to the formation of lavas and ig deposits to regional extension. In the second phase, there is a type of comer canism, with the formation of lavas and peralkaline ignimbrites. The last p have a calc-alkaline volcanism, with the emplacement of products with te pects typical of pyroclastic flow.

The volcanic outcrops in the 'Punta delle Oche' (north island), where room stone is located, are ignimbritic rocks (with a calc-alkaline affinity l.s in the latter phase.

2.2 The Elephant Stone

Until laserscan technology, this monument was not really surveyable, th shape, the huge massive structure was a real problem for anyone who would alize a serious survey of the whole stone. Thanks to the laserscan techn work became as easy as a complete photographical campaign. The older su lished years before, was about the tombs and was a good work, but it was classical bidimensional set of drawings, moreover it was aimed to documen ancient graves, and gave no information about the stone in itself. To face thi choose to use a Leica HDS 3000 panoramic scanner, based on the time of fl ogy. This was done for two reasons: for first this scanner is capable to gat accurate set of points from a very short distance and this was a very importa to allow the survey of the inner parts of the graves. Secondly this scanner pable to gather a very accurate result from a long distance, so it was possib the scanner in the upper parts of the hill in front of the stone and take the su upper parts with the same quality of the all the rest of the monument. To high quality result in the overall operation the laserscan survey was supp complete topographical survey, aimed to build a specific network of all t targets placed on the monument and absolutely necessary for a clean recons the single scans. It is important to remember that the use of a topographical not only fundamental because of the high level of accuracy in the registratio and for the better and easier scanning planning; it is important because wh pographical network is planned, a series of permanent points are placed on t around the monument. Those special points can remain placed in the site years; so if there is the need for a new survey, for example if it happens tha the monument is damaged, or for simple monitoring needs, it is possible really accurate comparing of the two surveys according to points which are e the monument. In facts it would be possible to reply a new survey from any tion of the laserscan and there will be no need to have a complete new sur also a single part of the monument can be measured again.

The new survey can be placed exactly on the old one according to the to cal survey, based on some of the old points left on the area during the first d vey. In this way, having a reference system based on the general environme to monitor any change not only in the shape of the stone but also in its posit the system of the lower tombs. In this way a good, almost complete cover stone was produced and a large amount of the landscape around the monu also taken. The overall pointcloud is made of almost twenty five millions points. The accuracy obtained was around six millimetres for each scans. scanner was placed inside the graves the use of a wireless access point was ful to have a remote control of the scanner from the outside.

The topographical network was based on six topographical stations and survey of the almost forty targets applied on the stone and completely remo end of the whole scanning session.

2.2.1 First Data Treatments (Digital Survey Dataset)

The first step in the treatment of the collected data was, as usual, the registra the single scans in a unique digital model. This was done following two cla teria for this kind of survey: for first the single pointclouds were registered topographical survey, then they are geometrically compared (using the "c strain" function in Leica Cyclone) to improve the alignment of each pointc the other.

After the registration, the first operation taken on the resulting pointcl aimed to produce some simple sections all around the monument and a fir fied, surface model with almost all the occlusion holes fixed.

The whole first treatment was aimed to produce a massive, basic mo monument. This was a first surface model useful to verify the quality of the data. On the surface digital model a first texturing treatment was applied better evaluation of the result.

Bringing this model to generic rendering software like Maxon Cinema 4I testing how was versatile the obtained model. Inside this software it was p produce a series of rendering view of the digital model and it was possible environment to develop some 3D interactive simulations to allow a better the first result without the need to share the heavy and hard to manage s model. The 3D interactive simulations were developed using the Quicktim put, a pre-compiled system of visualization capable to bring the perception virtual space, with a visualization based on a pre-calculated series of fra overall effect is quite good, allowing a good sight on the whole model and a ploration of the shape of the monument without any need of complex navig tems. Obviously this was just a simple, first test to verify the quality of th while the whole project is planned to achieve a more complex structure.

All the process is aimed to produce three main results, each result inte other:

- The first result is to have a very high quality survey of the monument a precious documentation of the conditions of the stone in the Novemb
- The second result is to produce a set of popular and interpretative mod hance the possibility of using and sharing of the knowledge about this monument.

2.2.2 Final Data Treatments (Digital Survey Dataset)

The first part of the work over the data treatments clearly showed that an developed in a small simplification of the model can give a good looking re is interesting only for shape analysis and monitoring purposes.

The time consuming rendering and the impossibility to use the high model for real time access creates the need to face the modelling process in specific way. So a different approach was chosen, no more direct modellin pointcloud, but a process starting from a new rebuilt and optimized polygo and then a reconstruction based on the subdivision surface modelling.

The following steps in modelling produced a variable resolution model, switch gradually from a full resolution representation to a lower polygon r tion, crossing all the intermediate steps of the representation.

The keywords for this process of variable simplification were: edge lo ling, Re-Topology modelling. To greatly enhance the representation two digital modelling and texturing solutions were adopted, the classical textur procedure based on the photographical documentation campaign of the st specific Normal Mapping procedure based on the information coming fro resolution model in itself. In this way a whole new model was produced, no monitoring or accurate information extraction, but greatly suitable for multi representation.

The software workflow for the developing of this new multimedia orien was based on Pixlogic Zbrush and Maxon Cinema 4D.

A The whole process was aimed to develop a specific solution for th items, to produce a method to face and develop high performance mode shaped stones and natural monument, the case study operated on the Elep demonstrate the full opportunity offered by the method, capable to produ

Fig. 3. Rendering view of the three dimensional digital model of the elephant s

strength that link the procedure to the monuments the stone of the elephant
are the natural shape, the human artefacts producing smooth parts in the s
ing, the impossible task to define a regular geometric pattern as real solut
description of the monument; the real need to have a continuous variation o
of details while changing the representation scale.

2.2.3 The Volcanic Rocks of Elephant Stone

On the geological front of the analysis for this monument the some n
sample collection is just completed and the geological research unit is work
materials study. All the collected and treated information will be then linl
pointcloud model to create specific visualizations of the decay conditions o
ticular and unique stone.

The Elephant stone are pyroclastic rocks with welded from high- to med
and a strong heterogeneity, due to variable presence of lithic fragments,
(with various size, until to decimetre) and pumice into the matrix of sto
rocks have an open porosity ranging about from eight to 25% (in litho-clasts
fragments of lava-like ignimbrites with strongly welded); the matrix of th
clastic rocks, characterized from low- to medium-welded grade, the oper
varies about from 15% (into unaltered matrix) to 45% (in altered matrix)
sample strongly altered, the porosity comes to 50%.

What happens inside the vitreous matrices, already characterized by poo
original (Macciotta et al. 2001). Microscopic analysis indicated that the ign
Elephant stone have a porphyritic structure (with porphyritic index between
with phenocrysts of opaque minerals (magnetite and/or titanomagnetite), pl
± clinopyroxene and rare quartz. Actually, further analyses are in progress.

2.3 The Mushroom Stone

About the Carloforte Mushroom Stone it is possible to say "we just arrive t
large part of the stone remembering the "umbrella" of the mushroom
in March 2010, while a survey was planned for the end of may 2010. The r
is an ancient stone completely developed by the action of the atmosphe
(e.g. wind with marine aerosol, meteoric water, thermoclastism, etc.; see
2.4 Decay of stone witnesses) over a very articulated volcanic stone.

A particular alteration process has produced a kind of "umbrella" over a r
rock. The reasons of the fall are probably due to a natural issue, but this simp
lines how urgent is a survey of these fragile system. So, even if in its hardly
shape, the survey was done in June 2010.

The complex shape of this stone and the demanding walk needed to rea
all the instruments, made us prefer to operate with a light phase-shift scanne
Cam2 Faro Photon 80. The survey was based on spherical target system, to
reconstruction of each single scan into a unique model.

Fig. 4. The digital survey of the mushroom stone

The scans were taken in three series, a first series with the scanner place on the ground, a second series with the scanner on the tripod at medium ele a third series with the scanner on the tripod at the maximum elevation.

In this way it was obtained a very good coverage of the whole stone a fallen fragment, mainly too large and heavy to try to turn them on the other a scan of the opposite side, it was preferred to avoid this fearing to produc ther damage. A complete collection of sample and a first geological docume the whole stone and of the area around it was made.

A study about the various forms of macroscopic alterations was made o the gathering of small samples from monument stone.

All the digital survey data and all the geological data (physical, geoche petrographic characteristics of geomaterials) are now under development an in the next months it is planned to investigate what is effectively happened to collapse of the umbrella and to define a clear picture of the state of decay of th

2.4 Decay of Stone Witnesses

Aside from the late-stage syngenetic alteration processes, the pyroclastic Elephant and Mushroom stones are greatly affected by epigenetic alteration.

tion. In the first case (a), late-stage chemical alteration processes transforme the original paragenesis to a greater or lesser extent, altering the mineral asse the glass (with incipient devitrification) with the formation of new seconda als. In the second case (b), the mechanisms of physical degradation are p related by: 1) presence of soluble salts (from soil or atmosphere) that exert a zation pressure into open porous of stone; 2) differential thermal dilatation in normal day range of temperature and solar radiation; 3) absorption/desorpt stone of meteoric water (Columbu et al. 2008) or water from soil or air mo water hydration/dehydration of hygroscopic mineral (e.g. salts). Neverthele cay mechanisms of these two stone witnesses are different.

This depends, on the one hand, by different microclimatic conditions and of stone surface to atmospheric agents and, on the other hand, by differen and mineral-petrographic characteristic of geomaterials.

In fact, the Mushroom stone is located near to the sea (about 200 metres), Elephant stone is located about 3.3 kilometres from the sea. Moreover, the p rocks of Elephant have different petrographic features and then are more he ous, due to the greater presence of lithic fragments, lithoclast into the mat Elephant and Mushroom monuments there are diverse macroscopic forms o decay (decohesion, exfoliation, alveolation, differential degradation) and pr crypto- and ef-florescence.

These macroscopic forms are distributed differently in them extern surfa stone. In the Elephant the decay processes are mainly concentrated: 1) in part of the big block of stone (that rests directly on the soil and is charac presence of circulating water solution by capillarity), with strong backward profile of stone; in this zone differential degradation, with enucleation of l ments and lithoclast, and exfoliation are the principal alteration macroscopic on the top and median parts of Elephant stone that exposure to the SE-S-S where there is more frequent the solar radiation; in these zones strong a processes and physical degradation are more present, due to the differenti dilatation and diurnal cycles of moisture absortion/desorption; the alveolati sent mainly under the 'proboscis' of Elephant and into the outer room of ' janas'. In the other outer parts of the monument with exposure to the NE-N bio-deterioration agents (e.g. musk, lichens, etc.). In the Elephant stone, processes were observed. XRD analysis performed on the collected sample extern surface of parts of monument exposed to south and to west, indicated ence of hematite, consequently to alteration of Fe-Mg minerals.

Diffractometric analysis on other samples taken on the outer crust of pre indicated the considerable amounts of gypsum.

It is planned to investigate which is the origin of this phase; probably partially from meteoric precipitations because these have often a small q gypsum; this is formed by interaction of sulphur dioxide, acidic rainwater a pheric particles of $CaCO_3$.

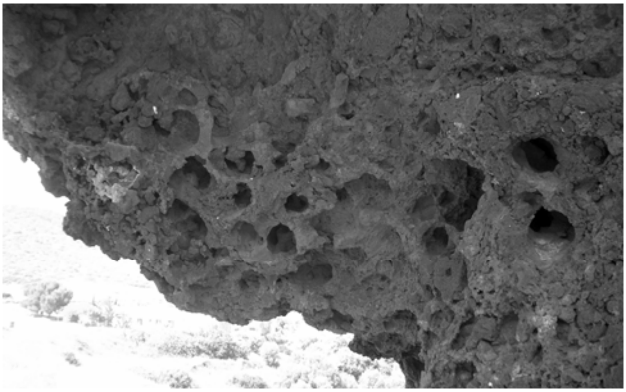

Fig. 5. Macroscopic alteration form of alveolation on the surface under the probos
phant stone of Sedini with the presence of salts within to the vitreous matrix of volca

In the Mushroom stone the decay (that produced a particular kind of “u
shows: 1) exfoliation in the stem of the mushroom; this alteration form i
trated: a) where there are mechanisms of water wash-out, that remove cons
flakes produced by other alteration processes, b) on face of stem exposed to
wind come from the sea. The meteoric water run along the stem by fracture
sures present into the top head of mushroom; on the base of first ma

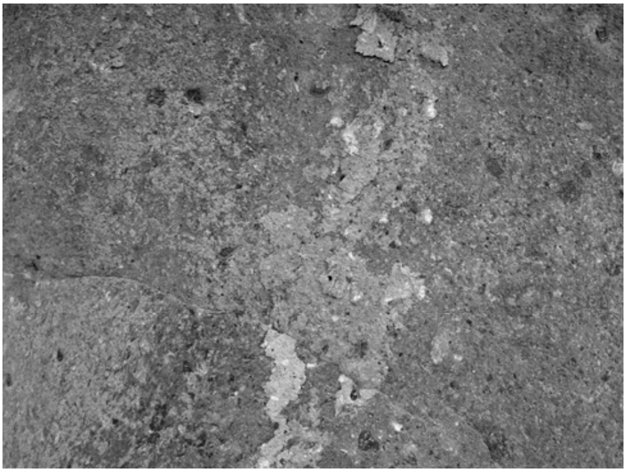

Fig. 6. Physical decay of stem of Mushroom stone of Carloforte with exfoliation p
mechanisms of absorption/desorption and wash-out of meteoric water

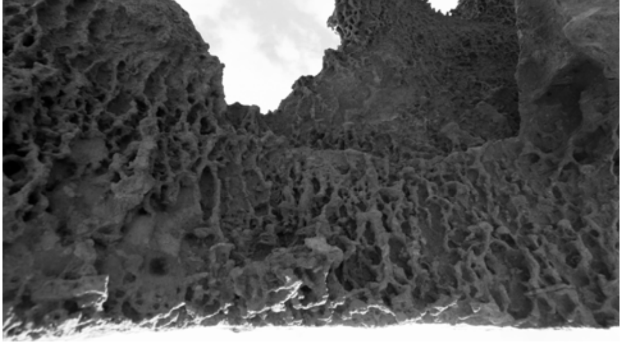

Fig. 7. Macroscopic alteration form of alveolation under the head of Mushroom stone of C

observation, probably parts of head collapsed due to the presence of these f articulated alveolation (that penetrated until about 8 cm from surface belo head where coexist two important factor of decay: a) physical decohesion therefore to continue mechanisms of absorption/desorption of meteoric wa midity, containing a small quantities of seawater (with salt), (note: the thi head of mushroom is about maximum 30 cm), b) turbulence induced ne mushroom by the sea-wind, which can frequently remove the thin flakes weathered.

In the near future it is planned to investigate what is happened to cause c of the "umbrella" (with determination of properties of resistance physical-r of stone under stress of own lithostatic load) and to define actually state o this natural stone monument.

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